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# PATENT SPECIFICATION

(11) 1 592 960

1 592 960

(21) Application No. 53920/77 (22) Filed 24 Dec. 1977

(44) Complete Specification published 15 July 1981

(51) INT CL<sup>3</sup> B29D 27/00

(52) Index at acceptance

B5A 1G10 1G4X 1G7AX 1R214B 1R314C1A 1R314C1C  
1R314C1D 1R314C1F 1R314C1X 1R314C6 1R455 2A1  
2A2 2A3 2M 2P2 2U2 T17P

C3C 104 106 107 110 112 150 156 159 181 184 350 351 358 375  
383 405 427 452 455 521 530

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(19)



## (54) PROCESS FOR PRODUCING EXPANDED ARTICLE OF THERMOPLASTIC RESIN

(71) We, SEKISUI KASEIHIN KOGYO KABUSHIKI KAISHA, a Japanese Company of No. 25, Minamikyobato-cho 1-chome, Nara-shi, Nara, Japan, do hereby declare the invention for which we pray that a Patent may be granted to us, and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to a process for producing an expanded article of a thermoplastic resin.

Processes for producing a foamed, thermoplastic resin article for use as an artificial wood with woodgrain pattern by extruding a molten foamable thermoplastic resin through a nozzle having a number of apertures to expand the resin are described in, for example, U.S. Patent Nos. 3,720,572 and 3,993,721 and Japanese Patent Application (OPI) No. 59,969/76.

These processes for producing a foamed thermoplastic resin article are primarily concerned with a polystyrene resin. Since a polystyrene resin has a good foamability, the desired foamed resin articles can be produced continuously over a long period of time according to the processes described in the above mentioned documents.

However, in applying the above conventional processes to crystalline thermoplastic resin other than polystyrene, e.g., polypropylene, a resin containing polypropylene as a major component or a polyamide, it is very difficult to produce foamed resin articles of good quality continuously. No process suitable for foaming such crystalline thermoplastic resins has so far been used practically. That is, since polypropylene and polyamide resins are crystalline thermoplastic resins, their melt viscosities are sensitively temperature-dependent, and the viscosity suitable for their expansion is in a narrow temperature range close to the temperature at which the resins crystallize. Generally, it is extremely difficult to effect extrusion and expansion while controlling the nozzle temperature in such a narrow temperature range. In extruding such resins using a nozzle having a number of apertures, the resin streams flow in some portions with difficulty and partially crystallize and solidify to prevent expansion. In addition, such adverse effects on uniform, stable extrusion in the respective apertures make it difficult to produce a high quality, foamed crystalline thermoplastic resin article.

It was believed that such problems could be solved by controlling the temperature of the nozzle with a high degree of accuracy in order to avoid crystallization and solidification of the resin. In fact, however, it is technically difficult to control the nozzle temperature within a critical narrow range suitable for expansion in order to avoid crystallization, since extrusion molding involves many factors which may vary widely. For example, to equip a nozzle with a temperature controlling mechanism as disclosed in Japanese Patent Application (OPI) No. 59,969/76 is not satisfactory for a polypropylene resin or a polyamide resin; the resin crystallizes in parts of a number of apertures which prevents stable extrusion of resin streams. In addition, when the resin is cooled through a cooling member or frame adjacent to a nozzle having a projection in its center as described in U.S. Patent 3,993,721, it is difficult to extrude polypropylene resin quantitatively in respective apertures of the nozzle because partial plugging of the apertures occurs. Thus, stable production of a foamed thermoplastic resin

article, such as a foamed polypropylene resin article or a foamed polyamide resin article, having good quality over a long time was found to be very difficult.

It is an object of the present invention to obviate or mitigate the above problems.

As a result of extensive investigations to solve the above-described technical problems associated with the conventional processes in the continuous production of a crystalline thermoplastic resin foamed article used, for example, as an artificial wood with woodgrain pattern, it was found that desired foamed resin articles with woodgrain pattern can be stably and continuously by the process of the present invention.

Accordingly, the present invention provides a process of producing an expanded thermoplastic resin which comprises passing a resin stream through an extrusion zone while maintaining the resin at a temperature above the melting point thereof, dividing the resin stream in the extrusion zone into a plurality of separate streams, passing said separate streams into a periphery confined zone whose boundary is maintained at a temperature of at least 30°C lower than the temperature of the separate resin streams at the division thereof, the cross-sectional area occupied by said separate streams being 5 to 30% of the cross-section area of that portion of the peripherally confined zone which receives said streams, thereby forming in the confined zone a plurality of soft expanded resin strands corresponding in number to the number of strands, the strands expanding into surface contact with each other in the confined zone to fuse and bond together to form a bonded expanded resin mass while gases generated in the course of extrusion and expansion are simultaneously removed, passing the bonded mass into a peripherally unconfined zone to permit the mass to expand further while still in a softened condition, passing the further expanded mass into a peripherally confined receiving zone of a smaller cross-sectional area than the further expanded mass, and cooling the mass to form an expanded article.

Preferably, said resin is a polypropylene resin, a polypropylene copolymer resin, a mixture of a polypropylene resin and less than 50% by weight of another thermoplastic resin, or a polyamide resin.

Most advantageously, the polypropylene copolymer resin is a copolymer of propylene and ethylene.

Conveniently, said resin is a mixture of polypropylene resin and 1% to 30% preferably 2% to 25%, by weight of the mixture of said another thermoplastic resin.

Typically, the temperature of the resin stream in the extrusion zone is maintained up to 20°C, preferably up to 10°C, above the melting point of the mixture.

Preferably, the peripherally confined zone is maintained at a temperature in the range of 50°C to 100°C lower than the temperature of the resin strands prior to the latter leaving the extrusion zone.

Advantageously, the peripherally confined receiving zone has a cross-sectional area smaller than that of the further expanded mass by 5% to 50%.

In the accompanying drawings:—

Fig. 1 is a longitudinal sectional view showing part of an apparatus for performing an embodiment of a process of the present invention,

Fig. 2 is a longitudinal sectional view of a nozzle used in the apparatus of Fig. 1,

Fig. 3 is a cross-sectional view of the nozzle of Fig. 2,

Fig. 4 is a longitudinal sectional view of another form of nozzle,

Fig. 5 is a front view of part of the nozzle of Fig. 4,

Fig. 6 is a longitudinal sectional view of a further form of nozzle, fitted with a cooling member,

Fig. 7 is a view similar to Fig. 6 showing the nozzle fitted with a further cooling member,

Fig. 8 is a longitudinal sectional view of a further nozzle,

Fig. 9 is a front view of the nozzle of Fig. 8,

Fig. 10 is a longitudinal sectional view of a still further nozzle, fitted with a cooling member, and

Fig. 11 is a front view of the nozzle of Fig. 10.

Referring now to Fig. 1, the apparatus basically comprises an extruder E, a temperature controller 1, a die 2 having a nozzle 3 including a projection 31, apertures 32 and a gas-releasing groove 33, cooling members 4 and 4' having channels 41 and 41' respectively, for a cooling medium, a receiving member 5, a

plate 6 a water bath 7, rolls 71 a surface processing apparatus 8 take-up rolls 9. A foamed article produced by the apparatus is indicated by the reference numeral 100.

5 The temperature controller 1 is provided at the downstream end of the extruder E and includes a torpedo shaped hollow member 12 in an outer cylinder 11, a space between the member 12 and cylinder 11 defining a resin channel 13. A heating or cooling medium is circulated in the cavity in the member 12 through inlet and outlet pipes 14 thereby to heat or cool the member 12. The outer cylinder 11 has a helical channel 15 formed therein. A heating or cooling medium is passed along the channel 15 via pipes 16 thereby to heat or cool the outer cylinder 11. Thus, molten resin flowing through the channel 13 is controlled to a temperature within an extremely narrow range suitable for subsequent expansion. In this embodiment, band heaters 17 are provided around the outer cylinder 11.

15 The die 2 is provided downstream of the temperature controller 1. A band heater 21 is provided around the die 2, and a resin channel 22 in the die 2 is provided with a resin stream-adjusting plate 23 having a number of openings therethrough. Since the resin stream in resin channel 22 flows faster in the central portion thereof than at the periphery the diameters of the openings in resin stream-adjusting plate 23 are so arranged that the flow of resin becomes uniform across the cross-section of the channel 22. The resin channel 22 is provided with a narrow neck 24 between the resin-stream-adjusting plate 23 and the nozzle 3, the neck 24 serving to prevent premature expansion and maintain the expansion pressure.

25 The nozzle 3 has a number of apertures 32 therethrough arranged in two rows and has a conical solid projection 31 on an upstream side thereof between these two rows. The nozzle 3 also has a gas-releasing groove 33 which is provided between the two rows of apertures 32 on the downstream side of the nozzle. Further, the cooling member 4 is in the form of a square frame having a plurality of channels 41 for controlling temperature and is connected to the downstream end of the nozzle 3. A space 42 is provided in the member 4 to reduce the area of contact between the member 4 and the die 2 in order to reduce direct transmission of heat from die 2. The other cooling member 4', also in the form of a square frame, has a slightly greater cross-sectional area than that of the member 4. The member 41' is provided with a space 42' similar to the aforementioned space 42. Both ends of the above-described gas-releasing groove 33 are open to atmosphere and gases generated after extrusion through the apertures 32, are directly released into atmosphere. The receiving member 5 is tapered and serves to compress the expanded mass so as to reduce the cross-sectional area thereof with a given compression ratio. The plate 6 controls the appearance and the cross-sectional dimensions of the expanded mass. The water bath 7 serves to cool and solidify the expanded mass. The rolls 71 are provided in the water bath 7, which cools the mass while controlling its cross-sectional dimensions. The surface processing apparatus 8 is provided downstream of water bath 7 and is constituted by heating and tapered compressing member 81 and subsequent cooling member 82, whereby the surface of the resin foamed article is reheated and compressed to such a degree that the cross-sectional area of the foam is reduced by 3% to 20% as compared with the cross-sectional area prior to the pre-heating and the compression to provide a hard surface layer and a high dimensional accuracy of the resulting shaped expanded article. The take-up rolls 9 serve to transport the resulting shaped, expanded article out of the apparatus.

50 In the above-described production apparatus, the resin is kneaded with, for example, nucleating agents, blowing agents and pigments and melted by means of the heated extruder E. The temperature controller 1 controls the temperature of the mass so that it is slightly higher than the temperature suitable for expansion and also above the crystallization temperature of the resin. The resin stream is made uniform upon passing through resin stream-adjusting plate 23 and then passes to the nozzle 3. Subsequently, the resin stream is divided into a plurality of separate streams (two streams in Fig. 1) by the projection 31 without causing dwell or hold-up of the resin, and then again separated by the apertures 32. The resin stream is then finally extruded into the cooling member 4 thereby to form a plurality of soft expanded resin strands corresponding in number of apertures 32. Gases generated at the exit of the nozzle 3 in the course of extrusion and expansion are directly removed by releasing into atmosphere through the gas-releasing groove 33 and never enter into the expanded mass. The plurality of soft

expanded resin strands which have been extruded and expanded after being extruded through the apertures 32, are cooled from the surface thereof by the cooling member 4, adjusted to a suitable temperature for expansion which is lower than the temperature of the nozzle 3, thus being successively expanded and fusion bonded together in the cooling member 4 to form a bonded expanded resin mass.

Then, the resulting bonded mass is further successively expanded and allowed to pass through the receiving member 5 which reduces the cross-sectional area of the resin mass. After this, the mass passes through the plate 6 where the cross-sectional dimensions of the mass are controlled and the bonded mass is more strongly fusion-bonded by compression. The mass is then directly cooled with water in the water bath 7 while being supported by rolls 71. The thus obtained cooled expanded resin mass is compressed by 3% to 20% whilst being heated by means of the heated compressing member 81 and then cooled by the cooling member 82 respectively to impart a hardness and luster to the surface of the mass. Thus, there is obtained a shaped expanded article 100 with good dimensional accuracy.

Referring now to Figs. 2 and 3, it will be seen that this embodiment of nozzle 3 has a horizontally extending projection 311 between two rows of equidistantly spaced apertures 32. Projections 312, 312 are in contact with the upper and lower sides respectively of the resin channel 22 and extend to the upper and lower row of apertures 32 respectively. The nozzle 3 is also provided with the gas-releasing groove 33 in the same manner as nozzle 3 shown in Fig. 1. In the nozzle 3 illustrated in Figs. 4 and 5 two rows of horizontally extending projections 31 are provided on each side of which are provided rows of equidistantly spaced apertures 32, thus making 3 rows in all.

In the type of nozzle 3 illustrated in Fig. 6, a screen containing further channel 41 is additionally provided in the cooling member 4. In Fig. 7, the cooling member 4 is in the form of a frame of square cross-section. The flow passage within the member 4 narrows slightly in the direction of extrusion and is connected at its downstream end with the member 4' over a surface in which space 42' is provided.

In the nozzle 3 of Figs. 8 and 9, a gas releasing groove 33 having both ends opening to atmosphere is provided inside the nozzle 3, and equidistantly spaced gas-releasing holes 331 are provided on the downstream side of the nozzle and between two rows of apertures 32.

In the nozzle 3 of Figs. 10 and 11, projections 31 defined by arcuate depressions are provided on the upstream side and a number of perpendicularly intersecting gas-releasing grooves 33 having both ends open to atmosphere are provided on the downstream side. This nozzle 3 is provided with a cooling member 4 having a passage which tapers inwardly in the direction of extrusion.

The apertures 32 in the nozzle 3 are 1 mm to 4 mm in diameter in the case where the apertures are circular and 10 mm in land length and are arranged so that their centres are spaced 2 mm to 20 mm apart. The apertures 32 permit the passage of the foamable resin mixture when the temperature of nozzle 3 is higher than the melting point of the resin used. Each projection for preventing dwell or hold-up of the molten resin on the upstream side of the apertures 32 is more effective when its surface is subjected to a smoothing finish or to chromium plating of Teflon (Registered Trade Mark) coating. It is necessary to provide a gas-releasing means on the outlet side of apertures in the nozzle in order not to contaminate resin streams with gases generated upon extrusion and expansion through respective apertures 32. For this purpose, there is provided the gas-releasing groove or grooves, which are open to atmosphere, on the outlet or downstream side of the nozzle.

Where wide of large moldings are formed, it is preferable to connect a suction pump to the gas-releasing groove or grooves to assist in removal of the generated gases.

The cooling member 4 is provided not only for cooling but also for fusion bonding a plurality of the soft expanded resin strands which have been extruded through the nozzle and slightly expanded. Cooling occurs to a temperature suitable for expansion while free expansion is restricted by the frame-like cooling member. Total cross-sectional area of the resin flow path through respective apertures must be 5% to 30%, preferably 5% to 15% of the cross-sectional area of resin channel in the cooling member 4, i.e. immediately downstream of the apertures. If the cross-sectional area of resin flow path through the apertures is less than 5%, contact of the strands with the inner surface of the member 4 is so

weak that the strands are difficult to cool and become poor in foamability, whereas if the cross-sectional area is more than 30%, gases released from the strands extruded at a higher temperature than the temperature suitable for expansion are not completely removed through the gas-releasing groove and remain between respective strands to form voids or gaps in the resulting article or, since respective strands cannot be fully expanded within the cooling member, cells would rather be elongate in an extrusion direction than in a transverse direction to provide a foamed article having weak compression strength.

In addition, the cross-sectional area of the resin channel in the cooling member may be increased or reduced in the direction of extrusion. That is, the cross-sectional area of the outlet of the cooling member may be increased or reduced by 10% as compared with that of the inlet of the cooling member and the length of the cooling member is preferably 30 mm to 100 mm. Where the expansion force is weak, this length is preferably increased. Also, the temperature of the cooling member must be adjusted to a temperature lower than that of the nozzle. It is necessary to adjust the temperature of the cooling member to at least 30°C below the melting point of the resin. A preferred range is 50°C to 100°C below the melting point. For this purpose, it is desirable to provide a plurality of channels in the cooling member and to circulate a cooling medium which has been adjusted to a desired temperature through the channels.

For example, when using a polypropylene resin or a polypropylene resin having 1 to 30% by weight of another thermoplastic resin mixed therewith, the melting point of the resin mixture is 150 to 170°C and the temperature of the cooling member is 50 to 120°C, preferably 70 to 100°C. If the temperature of the cooling member is higher than about 120°C, either the resin strands are not fully expanded, or the resin adheres to an inner wall of the frame, or the cells present in the expanded resin rupture. On the other hand, if the temperature of the frame is less than about 50°C, a hard skin is formed on the surface of the resin strands in the frame and thus, the resin strands are not fully expanded, and sometimes, the resin solidifies in the nozzle due to the cooling effect of the cooling member.

The cross-sectional shape of the resin channel of the receiving member 5 is similar to that of the resin channel in cooling member 4, and it is preferable to reduce by 5% to 50% the cross-sectional area of the expanded mass having been expanded with an expansion ratio of 1.2 to 2.5 upon extrusion through the cooling member into an unconfined zone. The receiving member 5 can be defined by sets of parallel rolls with one set being perpendicular to the other set. The surface of the expanded mass after passage through the member 4 into the peripherally unconfined zone is uneven, and reduction by less than 5% is not enough to smooth the surface, whereas reduction by more than 50% causes too much resistance.

Thus, expanded resin strands are strongly fusion bonded through constriction pressure in this location to provide a bonded mass having good dimensional accuracy, which can be used, for example, as a smooth surface artificial wood with distinct woodgrain pattern.

Thus, by appropriately choosing the shape of the channels for the resin, such as in the nozzle, the cooling member and receiving member, an expanded resin elongate article of sheet or slab form or of circular or complex cross-sectional shape, such as doorsill or threshold shape can be obtained. Further, an expanded resin article having a high compression strength can be produced by arranging for each strand in the expanded resin article to have a long rectangular or approximately triangular cross-sectional shape.

Examples of resins which can be used in the process of the present invention are (1) a polypropylene resin, a polypropylene copolymer resin, a mixture of polypropylene and less than about 50% by weight of a thermoplastic resin, or (2) a polyamide resin.

Polypropylene resins which can be used are preferably ones having a melt index of less than about 5 (measured according to ASTM D-1238, hereinafter the same).

Examples of polypropylene copolymer resins which can be used include an ethylenepropylene copolymer resin.

Examples of thermoplastic resins which can be blended with a polypropylene resin are a polystyrene resin, preferably one having a melt index of less than about 15; a polymethyl methacrylate resin, preferably one having a melt index of less than about 5; a high density polyethylene resin, preferably one having a melt index of less than about 3; a polycarbonate resin; an acrylonitrile-styrene copolymer resin, preferably one having a melt index of less than about 7; a polyamide resin;

and the like. These resins are blended usually in a proportion of 1% by weight to 30% by weight, preferably 2% by weight to 25% by weight, based on the total resin components. Blending polypropylene with these resins serves to improve foamability of the polypropylene resin and to provide a stable molding property, thus good resin foams being continuously produced. Of the above-described resins to be blended, a polystyrene resin a polymethyl methacrylate resin and a high density polyethylene resin are particularly preferable.

Examples of polyamide resins which can be used alone are nylon 6, nylon 66, nylon 12 and the like. A particularly preferred example of polyamide resins is nylon 12.

In the present invention, various foaming agents can be used. Examples of foaming agents are easily volatile liquids of aliphatic hydrocarbons such as pentene, butane, propane, petroleum ether, etc., or halogenated hydrocarbons such as monochloromethane, trichlorofluoromethane, dichlorotetrafluoroethane etc., and thermally decomposable foaming agents such as azodicarbonamide, dinitrosopentamethylenetetraamine, etc. These foaming agents can be previously mixed with the resin to be fed to an extruder, or can be poured into the extruder to mix upon extrusion. The amount of the foaming agent can vary widely depending upon the desired expansion ratio, but is usually about 1 to about 15% by weight based on the total amount of the resin composition.

In order to uniformly form fine cells in the resin, addition of a foaming aid or a nucleating agent in addition to the above-described foaming agent is desirable. Examples of such additives are fine powdery talc, silica powder, a mixture of sodium bicarbonate and citric acid, and the like, which are well known in the art.

The process of the present invention is constituted as described above and, since the expanded resin strands which have been extruded through apertures in the nozzle and once expanded are adjusted to a suitable temperature for expansion by means of the frame, enables the continuous production of an expanded mass of good quality. On the other hand, the temperature of the nozzle itself can be maintained at a comparatively high level, and hence neither crystallization nor solidification occurs in the apertures of the nozzle, thus not causing change in extrusion and expansion. This point also ensures stable extrusion production of a foamed article with good quality.

In addition, the present invention enables the direct release, into the atmosphere, of gases generated in the course of extrusion and expansion, and enables the production of a wide or large foamed article having no voids or gaps between a plurality of expanded resin strands due to the generated gases.

The thus obtained shaped expanded article is superior to polystyrene foams in heat resistance, chemical resistance and toughness without producing black smoke upon combustion, and hence it can be suitably used as materials for a heating apparatus or a hot water-feeding equipment or as structural materials for apparatus for producing industrial chemicals, packaging materials, feeding materials, press molding materials, etc.

The present invention will now be illustrated in greater detail by referring to the embodiment using the molding apparatus shown in Figure 1. Unless otherwise indicated, all parts, percents, ratios and the like are by weight.

#### Example 1

A mixture prepared by uniformly mixing 2 parts of fine powdery talc (as a nucleating agent) and 0.2 part of a brown pigment with 100 parts of polypropylene resin (Noblen MH-8, made by Mitsubishi Petrochemical Co., Ltd.) was charged into a hopper of extruder E, which was set to 200 to 250°C in the feed portion and 150° to 170°C in the forward end. The mixture and a foaming agent of butane added into the extruder on the way were uniformly kneaded in the extruder and transferred to the resin temperature controller. The mixture was transferred to nozzle 3 maintained at a temperature of 170°C to 180°C through resin stream adjusting plate 23 and extruded into frame 4 and expanded on the outlet side of a number of apertures in nozzle 3. Then, a plurality of soft expanded resin strands extruded through respective apertures were fusion bonded together in the above-described frame 4 controlled by circulating an oil at 85 to 90°C and also circulating water at room temperature into frame 4' with the apparent shape maintained and subsequently, the bonded expanded resin mass was once peripherally unconfined to permit further expansion to such an extent that the cross sectional area thereof became 1.2 to 2.5 times that of the opening of mold 4, then constricted by 5 to 50% in sectional area base on the sectional area of the secondary expanded resin mass



by means of receiving frame 5. The thus constricted resin mass was cooled by passing through water bath 7, and surface-processed by surface processing apparatus 8, followed by continuously drawing by take-up rolls 9. Thus, there was obtained foamed article 100 having luster, hard surface and woodgrain pattern wherein lines of juncture formed in a longitudinal direction between respective resin streams appeared as brown lines, thus providing a wood-like appearance.

In this example, a nozzle of the structure shown in Figures 2 and 3 was used as nozzle 3. That is, at the forward end of die 2 was provided nozzle 3 having a rectangular cross-section of 22 mm in height and 152 mm in width and having 96 apertures of 1.6 mm in diameter in the center thereof aligned in two parallel rows with a vertical distance of 10 mm, with respective apertures in each row being spaced from each other at a horizontally equal distance of 3 mm. Outlet side of nozzle 3 was in a vertical form, and gas-releasing groove 33 of 6 mm in width and 5 mm in depth communicated to atmosphere was provided between the upper and lower rows of apertures 32, 32,.... In addition, frames 4 and 4' which were connected to each other had a section, in longitudinal direction, of 13 mm in height and 150 mm in width, had a length of 35 mm in parallel to the extrusion direction, and had an opening of 14×152 mm in cross sectional and 35 mm in length, the inner surface of which was uniformly coated with Teflon (Registered Trade Mark). In addition, the frame contained channels 41 for circulating a heat transfer oil and channels 41' for circulating cooling water provided in upper and lower parts of the mold. In the further stage, receiving frame 5 with a cross section of 13×150 mm, plate 6, and rolls 71 having an opening of rectangular cross section in a longitudinal direction for dimension control were provided, followed by a water bath for cooling the foamed resin mass with water, wherein the foamed resin mass was cooled while being supported and constricted by rolls 71. Then, the cooled resin foam was guided to surface-processing apparatus 8 comprising heating and compressing plates 81 and cooling plates 82 to reduce the sectional area of the resulting article by 3 to 20% to obtain smooth surface expanded article 100 having good surface luster, surface hardness and compressive strength.

The expanded article 100 thus prepared was a plane sheet of 12 mm in thickness and 150 mm in width having been expanded 7.3 times. The resulting sheet had a cross-sectional structure comprising two parallel rows of fusion-bonded strands, each strand having a height of 6 mm and a width of 3 mm. They did not contain voids at the interface between fusion-bonded resin foam streams, and the surface thereof had straight lines of juncture between resin foam streams, which provided the appearance analogous to grains of natural wood. Thus, they appeared like natural wood having the light-weight appearance thereof.

#### Example 2

A mixture prepared by uniformly mixing 1 part of fine powdery talc and 2 parts of azodicarbonamide with 100 parts of polyamide resin (Amilan X-502 made by Toray Industries Inc.) was fed into extruder E, which was set to 180 to 260°C. The mixture was extruded and expanded by nozzle 3 set to 160 to 170°C. The temperature of frame 4 was controlled at 100 to 110°C by air passing through channels 41. The thus extruded foamable polyamide resin streams were expanded in frame 4 and passed successively through receiving frame 5, plate 6 and rolls 71 shown in Figure 1 to thereby be fusion-bonded. Subsequently, the bonded expanded resin mass was water-cooled with water bath 7 and solidified to obtain the desired product 100 (an expanded article of the polyamide resin).

The expanded product 100 prepared was a continuous plane plate of 18 mm in thickness and 30 mm in width and the density thereof was 0.4 to 0.5 g/cm<sup>3</sup>.

In this example, a nozzle of the structure shown in Figures 10 and 11 was used as nozzle 3. That is, at the forward end of die 2 was provided nozzle 3 having a rectangular cross section of 24 mm×29 mm and having 39 apertures which are 1.6 mm in diameter and 10 mm in depth with respective apertures in each row being spaced from each other at a horizontally equal distance of 5 mm, as shown in Figure 11. At the outlet side of nozzle 3 was provided gas-releasing grooves 33 of 1 mm in width and 3 mm in depth transversely. In addition, a frame of the structure shown in Figure 7 was used as frame 4. That is, frame 4 had an orifice opening of 24 mm×29 mm at the inlet and 18 mm×29 mm at the outlet and of 20 mm in length, the inner surface of which frame being plated with chromium.

#### Comparative Example

When the temperature of nozzle 3 in the foregoing Example 1 was set to

160°C, there was observed slight breakage in the streams of foamable resin in apertures 32, whereas when the temperature of nozzle 3 was set to 150°C, there was observed complete breakage due to crystallization of resin, resulting in unstable extrusion and preventing subsequent expansion. Thus, there was not obtained a uniformly expanded article with high expansion ratio.

In addition, when frame 4 was cooled with the temperature-controlling oil raised to 120°C, expansion of the foamable extruded resin streams did not start unless the temperature of nozzle 3 was lowered to less than 160°C. However, the polypropylene resin used is liable to crystallize at this temperature of nozzle 3, and ruptured or broken inner portions are formed in the resulting article. Thus, there cannot be obtained satisfactory plane plates comprising polypropylene foam.

Next, the kind of resin and the amount of butane to be used were changed and the resin temperature at the forward end of extruder E, the resin temperature at the inlet of nozzle 3 and the temperature of frame 4 were controlled as shown in the following table using the molding apparatus used in Example 1 to obtain similarly a good resin foamed article with good quality.

TABLE

	Polypropylene Resin	Parts by Weight	*1	*2	*3	*4	*5	*6	*7	
20	Polypropylene <sup>*8</sup>	100	11.0	173	165	13×150 35 14×152 35	80	12×150	7.3	20
	Talc	2	9.8	177	167	13×150 35 14×152 35	80	12×150	4.5	
	Pigment <sup>*9</sup>	0.2								
25	Polypropylene <sup>*8</sup>	100	5.5	176	166	13×150 30	100	14×160	8.4	25
	Polystyrene <sup>*10</sup>	20								
	Talc	2	6.5	189	178	13×150 30	100	14×160	7.0	
	Polypropylene <sup>*8</sup>	100								
	Polystyrene <sup>*10</sup>	5	9.0	180	166	13×150 50	90	13×150	10.0	
	Talc	2								
30	Polypropylene <sup>*8</sup>	100								30
	Polymethyl methacrylate <sup>*11</sup>	20	8.3	189	178	..	90	..	8.0	
	Talc	2								
35	Polypropylene <sup>*8</sup>	100								35
	High density polyethylene <sup>*12</sup>	20	8.3	174	169	..	85	..	8.2	
	Talc	2								
	Polypropylene <sup>*8</sup>	100								
	Polycarbonate <sup>*13</sup>	20	7.6	191	174	..	90	..	11.8	
40	Talc	2								40
	Ethylene-propylene <sup>*14</sup>	100								
	Acrylonitrile-Styrene <sup>*15</sup>	20	8.3	187	169	..	85	..	6.5	
45	Talc	2								45
	Polypropylene <sup>*8</sup>	100								
	Polyamide <sup>*16</sup>	20	7.4	188	176	.. 50	85	..	8.5	
	Talc	2								
50	Ethylene-propylene <sup>*14</sup>	100								50
	Talc	2	10.0	172	164	13×150 35	78	12×150	5.0	
	Pigment <sup>*9</sup>	0.2								

\*1 Amount of butane added, % by weight

\*2 Temperature of resin at the forward end of the Extruder, °C

\*3 Temperature of resin at the inlet of nozzle, °C

\*4 Structure of frame mold; cross section, length (mm)

\*5 Temperature of oil circulated in the frame mold

\*6 Cross sectional area of molding frame in mm

\*7 Expansion ratio

\*8 Noblen MH-8, made by Mitsubishi Petrochemical Co., Ltd., was used as

a polypropylene resin, which has a melt index of 0.3 (ASTM D-1238), a heat-distortion temperature of 120 to 130°C (ASTM D-648), and a Vicat softening point of 145 to 150°C (ASTM D-1525).

- \*9 PPMSSC 46315(C), made by Dainichiseika Color & Chemicals MFG. Co., Ltd., was used as a rouge type pigment.
- \*10 Styron (Registered Trade Mark) 666, made by Asahi Dow Co., Ltd., was used as a polystyrene resin, which has a melt index of 7.5 (ASTM D-1238), a heat-distortion temperature of 94°C (JIS K-6871), and a Vicat softening point of 97°C (ASTM D-1525).
- \*11 Delphet 70H, made by Asahi Kasei Kogyo K.K., was used as a polymethyl methacrylate resin, which has a melt index of 0.5 (ASTM D-1238), a heat-distortion temperature of 92°C (ASTM-D-648), and a Vicat softening point of 120°C (ASTM D-1525).
- \*12 Hi-ZEX 7000F, made by Mitsui Petrochemical Ind., Co., Ltd., was used as a high density polyethylene resin, which has a melt index of 0.04 (ASTM D-1238), and a Vicat softening point of 124°C (ASTM D-1525).
- \*13 Iupilon S2000, made by Mitsubishi Edogawa Chemical Co., Ltd., was used as a polycarbonate resin, which has a heat-distortion temperature of 134 to 140°C (ASTM D-648).
- \*14 Noblen EC-9, made by Mitsubishi Petrochemical Co., Ltd., was used as an ethylene/propylene copolymer resin, which has an ethylene content of 10% by weight and has a melt index of 0.4 (ASTM D-1238).
- \*15 Tyril (Registered Trade Mark) 783, made by Asahi Dow Co., Ltd., was used as an acrylonitrile/styrene copolymer resin, which has a melt index of 3.5 (ASTM D-1238), a heat-distortion temperature of 94°C (JIS K-6871), and a Vicat softening point of 112°C (ASTM D-1525).
- \*16 Amilan X-5021, made by Toray Industries Inc., was used as a polyamide resin, which has a heat-distortion temperature of 52°C (ASTM D-648).

#### WHAT WE CLAIM IS:—

1. A process of producing an expanded thermoplastic resin which comprises passing a resin stream through an extrusion zone while maintaining the resin at a temperature above the melting point thereof, dividing the resin stream in the extrusion zone into a plurality of separate streams, passing said separate streams into a peripherally confined zone whose boundary is maintained at a temperature of at least 30°C lower than the temperature of the separate resin streams at the division thereof, the cross-sectional area occupied by said separate streams being 5 to 30% of the cross-sectional area of that portion of the peripherally confined zone which receives said streams, thereby forming in the confined zone a plurality of soft expanded resin strands corresponding in number to the number of strands, the strands expanding into surface contact with each other in the confined zone to fuse and bond together to form a bonded expanded resin mass while gases generated in the course of extrusion and expansion are simultaneously removed, passing the bonded mass into a peripherally unconfined zone to permit the mass to expand further while still in a softened condition, passing the further expanded mass into a peripherally confined receiving zone of a smaller cross-sectional area than the further expanded mass, and cooling the mass to form an expanded article.

2. A process as claimed in claim 1, wherein said resin is a polypropylene resin, a polypropylene copolymer resin, a mixture of a polypropylene resin and less than 50% by weight of another thermoplastic resin, or a polyamide resin.

3. A process as claimed in Claim 2, wherein said polypropylene copolymer resin is a copolymer of propylene and ethylene.

4. A process as claimed in claim 2, wherein said resin is a mixture of polypropylene and 1% to 30% by weight of the mixture of said thermoplastic resin.

5. A process as claimed in claim 2, wherein said resin is a mixture of polypropylene resin and 2% to 25% by weight of the mixture of said another thermoplastic resin.

6. A process as claimed in claim 2, wherein said thermoplastic resin is a polystyrene, a polymethyl methacrylate resin, a polyamide resin, a polycarbonate resin, an acrylonitrile-styrene copolymer resin or a high density polyethylene resin.

7. A process as claimed in any preceding claim, wherein said peripherally confined receiving zone has a cross-sectional area smaller than that of the further expanded mass by 5% to 50%.

8. A process as claimed in any preceding claim, wherein said expanded article is further passed through a heated compressing zone thereby reducing the

thickness of said expanded article by 3 to 20% and subsequently through a cooling zone to impart a hard lustrous surface to the article.

9. A process for producing an expanded thermoplastic resin article substantially as hereinbefore described with reference to Fig. 1 or Figs. 1, 2 and 3, or Figs. 1, 4, and 5 or Figs. 1 and 6 or Figs. 1 and 7 or Figs. 1, 8 and 9 or Figs. 1, 10 and 11 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1981  
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from  
which copies may be obtained.

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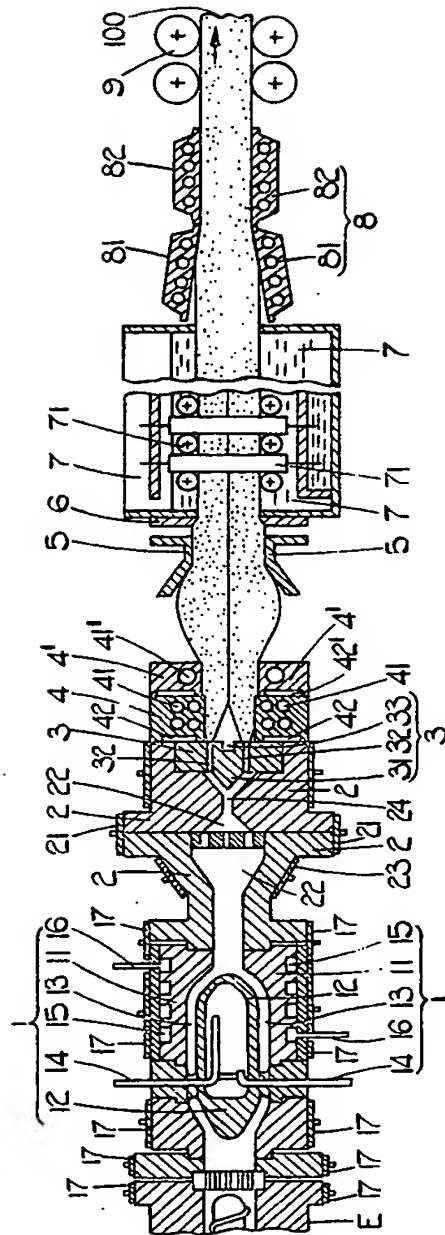


FIG. 1.

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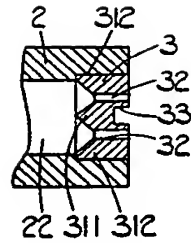


FIG. 2.

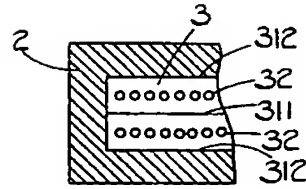


FIG. 3.

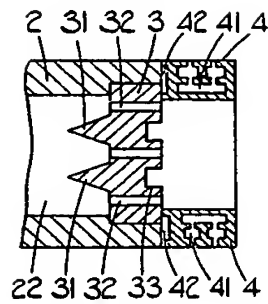


FIG. 4.

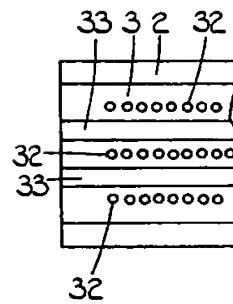


FIG. 5.

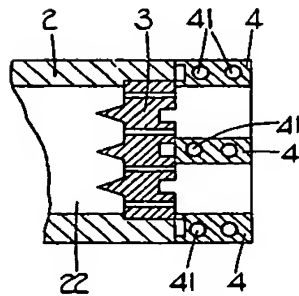


FIG. 6.

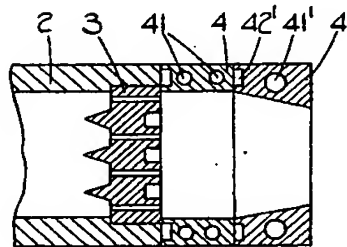


FIG. 7.

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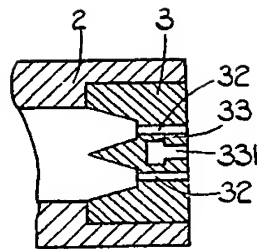


FIG. 8.

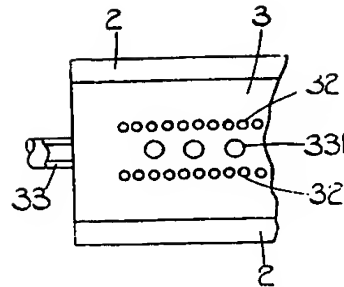


FIG. 9.

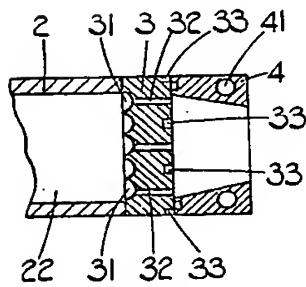


FIG. 10.

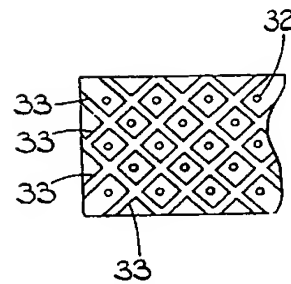


FIG. 11.

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